Children's Ways with Words in Science and Mathematics:
A Conversation across Disciplines

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Organized by
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Introduction

At a time when children from culturally and linguistically diverse backgrounds represent the fastest growing school-age population in the United States[1], too many of these children are failing in school science and mathematics. This has direct consequences for their sense of themselves as learners and thinkers, for their possible career trajectories, and for the well-being and resilience of our nation's social, economic and political life. The under-representation of poor and minority students in advanced sciences and mathematics is a complicated problem and, as the many attempts at addressing it attest, there are no simple solutions. Poverty, oppression, racism, lack of access to and history with formal schooling, social and economic stratification, and the like all contribute in powerful ways (Kozol, 1991; Mehan, 1991; Oakes, 1985, 1986).

The current science and mathematics education reform movements are in danger of leaving this problem unaddressed. While explicitly acknowledging their concern for "equity for all", these efforts have not taken up directly or seriously what the proposed reforms might actually mean for students living in poverty or from culturally and linguistically diverse backgrounds (AAAS, 1993; NCTM, 1989; NRC, 1996). Instead, like previous well-intentioned but limited reform movements, they assume that high quality curricula and authentic activity aligned with rigorous standards will result in high achievement. Historically, however, the details of education reform in this country have been typically worked out in mainstream contexts, with the underlying assumption that they can then simply be exported to non-mainstream contexts (e.g., urban and rural

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[1] There are now more than five million school-age children who come from homes in which English is not spoken. In several states, children from linguistic and cultural minorities represent more than 25% of the school-age population (e.g., AZ, CA, NY, FL, TX, NM) and in many large urban districts this figure is 50% or more (e.g., NYC, San Francisco, Los Angeles).

school systems, bilingual/English as a Second language settings). But, in fact, reforms rarely "trickle down" successfully, in part, because they have not been explicitly conceptualized in relation to diverse communities of learners or dynamic notions of culture (Secada, 1989; Gonzalez, in press).

How can science and mathematics education reform be reconceptualized with poor and minority students in mind? One avenue that seems worth pursuing is to pool what is known about issues of equity and access with what is known about reforming science and mathematics education to create a new community of educators and researchers concerned with, in the words of Deborah Ball (1997), being both "responsive to children and responsible to the discipline". This was the goal of "Children's Ways with Words in Science and Mathematics: A Conversation Across Disciplines."

Over the years, the fields of language and literacy development have made headway on understanding issues of educational equity for poor and minority children and on designing contexts in which these children learn and achieve. Much of this research has focused on what Shirley Brice Heath in her seminal 1983 study calls "ways with words." Heath (1983) documented the varying ways in which children and adults engage in practices such as argumentation or storytelling in school and out, who participates when and for what purposes, how ways of talking and interacting that seem 'natural' to members of one community are experienced as culturally strange by another.

Many studies in this tradition have since documented the effects of such differences on students' engagement with academic tasks and on the mutual difficulties of interpretation that students and teacher encounter in the classroom (Au, 1980; Ballenger, 1999; Cazden, 1988; Cazden, John & Hymes, 1972; Erickson & Mohatt, 1982; Gallas, 1995; Michaels, 1981; Moll, Estrada, Diaz & Lopes, 1980; Philips, 1982; Tharp & Gallimore, 1988; Trueba, Guthrie & Au, 1981). Teachers, like any human being engaged in communication, take in what children are trying to convey through the filter of their own knowledge, histories, and expectations. These filters include expectations as to what, for example, constitutes an explanation or an acceptable narrative, or what kinds of prior knowledge, experiences and skills support scientific reasoning. Thus they define in particular ways what counts as knowledge and what does not. Teachers can easily, and with the best of intentions, misunderstand children who say and do things differently from what they expect, children unlike themselves, often poor and minority children as well as children whose first language is not English.

While limited in number, a few studies document these difficulties of interpretation and evaluation specifically in science (Gee & Clinton, in press; Michaels & Bruce, 1989; Michaels & Sohmer, in press; Rosebery & Warren, 1999). Such studies show teachers and researchers, no matter how well meaning and dedicated, hearing poor and minority children as off-topic, confused, concrete rather than abstract in their thinking, magical rather than logical, lacking essential vocabulary, in short as not scientific in how they approached problems, in how they used language, or in their understanding. In several of these cases, the teachers and researchers have revisited and revised their initial interpretations to find the depth and coherence in the children's thinking and uses of language (Gee & Clinton, in press; Michaels & Sohmer, in press; Rosebery & Warren, 1999).

The Conference

The "Children's Ways with Words in Science and Mathematics" conference sought to bring together educators and researchers from diverse backgrounds and disciplines to explore issues related to learning and achievement in science and mathematics for poor and minority students. We explored 1) connections between children's ways with words and those characteristic of scientific and mathematical disciplines and 2) the varied ways in which students and teachers enact these relationships to foster learning.

Forty participants attended. Participants represented a range of disciplines and expertise: teacher-researchers, administrators, government personnel, and researchers and graduate students in anthropology, biology, cognitive science, developmental psychology, English, linguistics, literacy, mathematics education, physics, science education, and sociology.

Participants also varied in life experience: 35% were men, 65% were women; 55% were white, 45% were persons of color; 30% spoke a first language other than English; and we had origins a range of socioeconomic backgrounds and in families with varied histories of formal schooling.

At the conference, participants examined three cases of poor and minority students as they engaged in science or mathematics:

1) First and second graders from diverse ethnic, socioeconomic and family education backgrounds considered the question, "How do you know when something is moving?" The students' teacher modified her district's required motion curriculum with the intention of helping her students learn to see and analyze motion "through Newton's eyes." The students experimented by trying to move objects of different masses. In the focal episode, the teacher asked the students why they thought all of them could move some objects while only some of them could move other objects. This case offered intriguing contrasts in the ways different children approached the question, in what they saw as significant in the motion of objects, and in their ways with words and embodied actions.

2) Middle school students from diverse ethnic, socioeconomic, and family education backgrounds were presented with a fictive world in which they were asked to act as biological consultants and make recommendations about how to care for guppies taken from a polluted stream environment in Venezuela. The students were asked to model changes that would occur in the guppy population over several years, and then to design a tank environment that could support their growing population. Students shifted among different kinds of resources for animating and investigating relations between fish populations and their imagined habitats, including talk, embodied action, written texts, freehand drawings, symbolic descriptions of quantity, and dynamically linked networks, tables, and coordinate graphs. This case invited participants to explore what was "mathematical" in what students were doing; what was being animated and at what level as worlds were layered together in the guppy activity; what kinds of worlds were in play, who constructed these worlds, and how

they were articulated together as things got done; and if students were getting “more sophisticated”, how?

3) High school students in a Cape Verdean Creole bilingual program explored the relation between the motion of a quadratic function and its graph (a parabola), specifically the motion of a car that proceeds along a linear path and then reverses direction. The students discussed a number of questions including: whether the car slowed down and how their graphs did or did not reflect this; what a graph of slowing down would look like; whether the car could reverse direction without stopping; and what a graph of stopping would look like. This case allowed participants to explore the ways that real world objects, graphical representations and symbolic expressions interact in the construction of mathematical meaning; what students learned by analyzing the car’s motion and one another’s graphic representations; and the kind of mathematical community these students and their teacher constructed together.

Each case consisted of a classroom video episode, an accompanying transcript, and any additional materials needed to understand the episode. Participants worked in small groups to articulate a multi-dimensional perspective -- or perspectives -- on their case. They then shared their interpretations with the group and discussed how these multi-perspective analyses connected to their own ongoing work. A discussion followed in which participants articulated issues and questions that emerged from their work with colleagues from other disciplines. The conference ended with a discussion of possible future directions for research and practice on diversity in science and mathematics education.

Key Questions, Concerns and Suggestions for Future Directions

We have organized this report around five central themes: 1) Learning Science and Mathematics, 2) Teaching Science and Mathematics, 3) Development of a Profession of Teaching, 4) Development of Professional Communities, and 5) Theory and Method in Educational Research. In keeping with the open-ended, exploratory spirit of the conference, we present the key questions, concerns, and suggestions for future directions that came up during and after the conference as such.

1. Learning Science and Mathematics

The varied contexts of joint activity that formed the conference provoked ongoing and intense discussion of "what counts" as scientific and mathematical knowledge and practice, and how learning emerges in classroom interaction. In light of the cases, we considered significant features of mathematical and scientific learning communities focused on teaching for understanding. Among these were a focus on engaging students in a group practice aligned with important features of adult mathematical or scientific practice; community norms of mathematical or scientific accountability; a quality of open-endedness, in which possible questions and meanings are left open for later consideration. Exploration of these and other features in the context of the cases prompted discussion of the disjunctions found in many classrooms between what practicing scientists and mathematicians do and the limited ways in which schooling represents and assesses scientific and mathematical knowledge and knowing. In addition, the cases highlighted important commonalities in participants' views of significant scientific and mathematical learning and activity. Discussion focused on understanding the varied sense-making resources students used in the cases, including forms of argumentation, modes of explanation, embodied imagining and action, inhabiting and juxtaposing models, and so on. The following questions arose for further study:

a) How is disciplinary understanding formed, how does it emerge in classroom interaction? How can researchers and teachers better understand the nature of learning-in-interaction, and how to foster it?

b) How do skilled teachers use students' understanding, no matter how unusual, wrong or imperfect, as powerful levers for change?

c) How can classrooms be organized to support the development of group practices rather than to characterize individuals as successes or failures? In other words, is it possible to create classrooms that have no slots for "failure"? What are the various roles of teachers and students in such classrooms? How are issues of status and power negotiated between teacher and student as well as among students, e.g., who gets to talk, whose ideas are taken up, by whom, etc.?

d) What is the relationship between what we call "everyday" knowledge and practice and scientific or mathematical knowledge and practice? What implications do answers to this question carry for the design of classroom communities in mathematics and science? What are the connections between children's family and community knowledge, values, and practices and those of mathematics and science?

e) In what ways does research on classroom discourse connect with issues of instructional design in mathematics and science?

f) How close or distant are the uses of language in mathematics and science classrooms to the uses of language in professional mathematical or scientific practice? What implications do answers to this question have for discourse in science and mathematics classrooms?

g) As we create "authentic contexts" for learning science and mathematics, do we need to re-think, open up what counts as evidence of mathematical and scientific understanding? How is disciplinary rigor maintained in such contexts? Do we see changes in the participation, learning and achievement of typically marginalized students in such contexts? How do typically successful students fare?

h) What kinds of public demonstrations of competence are consistent with broader, more inclusive definitions of scientific and mathematical practice?

2. Teaching Science and Mathematics

Analysis of the cases gave rise to questions and concerns about the preparation and professional development of teachers, given the need to teach in ways that are responsive to children and responsible to the disciplines of science and mathematics. Teaching in this way is a complex act, requiring knowledge of both students' diverse ways of using language and of knowing and of the ideas and practices of the discipline under study. If taken seriously, this constitutes a rigorous re-definition of teaching and implies a significant rethinking of professional development and preparation. Participants posed the following questions for further research:

a) What are the forms of knowledge that teachers need in their everyday practice? What do teachers need to know about children's sense-making in relation to a) central ideas and practices of scientific and mathematical disciplines; b) uses of language and other semiotic systems (e.g., notational systems, tool use); and c) cultural resources and funds of knowledge.

b) How can teachers learn to see the intellectual strengths of children who are classified as "at risk"? What forms of professional preparation and development are needed?

c) What forms of learning in science and mathematics will help beginning and experienced teachers see the deep connections between disciplinary ideas and practices and children's understandings and sense-making? How can we bring teachers closer to the actual experience of learning new disciplinary content? What is needed to bring them closer to the experience of students for whom they design problems, investigations, activities?

d) Teachers need to be able to use both general theoretical knowledge (e.g., of teaching, learning, and the discipline) and highly situated local knowledge (e.g., of particular classrooms and particular children) in creative and flexible ways. What tools and forms of professional community can support teachers' ongoing learning?

e) How can teachers be helped to teach children they "don't like"?

f) What do these questions imply for the preparation of teacher educators and others who teach teachers?

3. Development of A Profession of Teaching

Two of the three cases featured teacher-researchers who were involved in developing and presenting the cases. These individuals engage in a professional practice that includes participation in a science or mathematics learning community, documentation of classroom episodes that focus on students' sense-making, analysis of discussion of these episodes with colleagues, and presentation of their research to other audiences. Alone and in concert with colleagues, they formulate and puzzle through questions and interpretations of classroom life. They do this 1) to better understand their children's ideas and ways with words and their own sense of the discipline, and 2) to refine and elaborate their own practice in an ongoing fashion. The grounded and public nature of this kind of practice prompted participants to pose questions regarding the development of a professional teaching community:

a) How does self reflection become an integral part of teaching?

b) How can good teachers be supported to develop contexts that allow them to confront questions about the quality of teaching? What is needed for teachers to become recognized arbiters of what constitutes good teaching and robust learning, in the same way that practitioners of other professions (e.g., medicine, engineering, law) are?

c) In light of b) immediately above, how can educational researchers, policy makers, administrators, and parents learn to see the intellectual and other strengths of teachers?

d) What is the nature of the knowledge that is produced by practitioners? How can the development, publication, and dissemination of such knowledge be fostered?

4. Development of Professional Communities

The conference was organized in a somewhat non-traditional way. Instead of formal paper presentations with discussion, the conference was designed to engage participants from diverse disciplines and life experiences in the analysis and interpretation of videotaped cases of classroom science and mathematics teaching and learning. The cases were chosen for their potential to highlight issues of diversity relating to 1) students' ways with words and ways of knowing, 2) different types of semiotic and representational systems, and 3) different types of curricular environments. Substantial time was devoted to close analysis of the cases in small groups. Participants valued greatly the opportunity to develop interpretations of complex cases in interaction with the perspectives, assumptions, and methods of individuals from a range of disciplines and life experiences. Participants enthusiastically endorsed this design and urged the following actions:

a) Creation of an ongoing forum for the work of this emerging community.

b) Expansion of participation in this community to include more researchers and teachers, as well as administrators, and policymakers. This was not put forward as a call for increasing the size of a given conference but for creating additional forums to incorporate this larger constituency.

c) Creation of forums to involve parents and children in exploring and discussing "what counts" as learning in science and mathematics, as high quality curriculum and teaching, and as meaningful assessment. We noted that there is as yet no publicly shared language for what is meant by high quality learning and teaching in urban classrooms.

d) Creation of a Special Interest Group (SIG) at AERA or a new professional society to further the aims of this emerging community.

e) Creation of a journal devoted to promoting multi-disciplinary research on learning and teaching in science and mathematics in urban settings.

5. Theory and Method in Educational Research

The conference was deliberately designed to bring diverse disciplinary perspectives into contact in the context of grounded discussion of cases of classroom interaction in science and mathematics. In the course of these discussions participants explored their respective theoretical and methodological assumptions and values in relation to the nature of learning and teaching, science and mathematics, language and other symbol use, classroom interaction, and the construct of diversity. In these discussions, always serious and at times heated, participants confronted productive differences and tensions among the metaphors and paradigms represented in the group. Various questions arose:

a) How can theory and method in the field(s) of educational research be informed by multi-disciplinary groups working on common data? For example, what constitutes the scope of a case, e.g., local interaction alone or local interaction combined with processes and events that take place in other times and places, including broad historical and social movements?

b) What does the construct "diversity" encompass, and how can it be used productively in analyzing learning and teaching? For example, how does diversity with respect to a) students' sense-making resources, b) different types of semiotic or representational systems, and c) different types of curricular environments play out in classrooms? For another, when is "linguistic diversity" a problem? How is it organized as a problem and by whom? When is it not a problem? Are there unexamined benefits of educational segregation, e.g., of a linguistic or ethnic group?

c) How is difference conceptualized in relation to individuals and groups? What is meant by "culture"? Is it an adequate theoretical construct? And how is it used in educational research and practice?

d) What are the ethical issues and responsibilities associated with researchers' public use of classroom videotape, in which teachers and students are engaged in the day-to-day work of doing mathematics and science?

e) How can we bring researchers closer to the actual experience of learning new disciplinary content, and is this a problem in our field? What is needed to bring them closer to the experience of the students and teachers for whom they design problems, investigations, activities, and the like?

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